about one-half mile wide, but the reports indicate that it was due to a straight-line squall and not to a tornado.

At Steubenville, Jefferson County, three brick buildings were demolished, many buildings unroofed, and the steamer *Queen City*, with fifty passengers aboard, was blown from the wharf. Reports from Steubenville indicate that the damage there was done by a tornado; the loss was estimated to be $30,000.

There seem to have been well-defined funnel-shaped tornado clouds observed in a few instances, and the best defined are indicated by the heavy arrows in fig. 1. It is probable, however, that the wind in most instances was of the thundersquall type or straight-line squall. These winds are always more severe in some places than in others, but the current is broad and they lack the narrow, well-defined path of great destruction that marks the work of the tornado.

Tornadoes occur very rarely in Ohio. They may be known by the funnel-shaped cloud that hangs downward from the mass of clouds above. Wherever this funnel dips down to the earth it usually demolishes everything in its path.

SEVERE WINDSTORM IN SOUTH DAKOTA.

By S. W. GLENN, Section Director. Dated Huron, S. Dak., July 16, 1908.

A severe windstorm, attended by heavy rain and in some places by heavy hail, past southeastward over Brule County, S. Dak., on June 27, 1908. At the village of Pukwana, Brule County, where the storm appears to have attained its maximum intensity, five large business buildings, two churches, and three dwellings were demolished and practically every other building in the village was more or less damaged. A very remarkable feature of the storm was the absence of any fatalities and cases of serious injury. The storm struck Pukwana at about 10:50 p. m., and the destructive wind lasted about one minute and a half. On an extensive ranch adjacent to Pukwana all of the buildings were blown down and some live stock was killed. The storm extended west to Chamberlain and east to Kimball, in the same county, but was much less severe at these places. Because of the late hour when the storm occurred, it is impossible to say whether or not it had the marked peculiarities of a tornado, but a gentleman who visited the place soon afterward describes the arrangement of the débris in such way as to lead to the opinion that it was. The path of the destructive wind was about one-half mile wide. It past south of Kimball, damaging a few buildings and killing some live stock in that portion of the country.

TIDES OF THE SOLID EARTH, OBSERVED BY DOCTOR HECKER.[1]

By R. L. FARIS, Assistant, Coast and Geodetic Survey.
[Read before the Philosophical Society of Washington, May 23, 1908.]

The author's purpose in his paper is to present the most important results of a series of horizontal pendulum observations made for the purpose of studying the disturbances of the plumb-line under the attractive influence of the sun and moon.

The deflections of the plumb-line, as the author states, can be directly brought about in two ways thru the influence of the sun and moon; first by the sun's radiation causing a deformation of the surface of the ground, and thereby a consequent tilting disturbance of the pendulum, but producing no change in the direction of gravity; second, by their attractive effect, producing a deflection of the vertical or change in the direction of gravity.

The first systematic attempt to determine experimentally the lunar disturbance of gravity appears to have been made almost thirty years ago by Prof. G. H. Darwin,[2] at the suggestion of Sir William Thomson. While his experiments with a vertical pendulum apparatus at the surface of the ground lead to no conclusive results, yet he indicates in his report, submitted to the British Association in 1881, the possibility of securing the suitable conditions and instruments "amply sensitive enough for such a purpose."

In the second report upon the same subject, a year later, in 1882,[3] after discussing the amounts of distortion of the earth due to barometric and tidal oscillations, Darwin remarks that, we can not know these data for a 500-mile radius about a station so we can get an approximate idea of the slope of the surface. Even if these data were known the heterogeneity of the geological strata would be an obstacle to correct computation. It was his opinion at that time even "with gravitational instruments of very great delicacy, in the most favorable site, the record would show incessant variations of which no satisfactory account could be given." He, therefore, viewed the problem of experimentally determining the lunar disturbance of gravity as "exceedingly remote." But he adds in conclusion that, "by choosing a site where the flexure of the earth's surface is likely to be great, it is conceivable that a rough estimate might be made of the modulus of elasticity of the upper strata of the earth for 100 or 200 miles from the surface."

A quarter of a century later, in editing the first volume of his collected professional papers, Darwin has added a note to the above report, in which he indicates that in the light of Doctor Hecker's recent work with the horizontal pendulum at Potsdam, he has now reason to change his former view in reference to the instrumental measurements of the lunar disturbance of gravity.

Doctor Hecker bases his conclusions upon a continuous series of pendulum observations extending thru the twenty-eight months from December, 1902, to May, 1905. The pendulums were mounted in a room especially designed for the purpose, at a depth of 25 meters below the surface of the ground. This room, built of brick laid with cement, was connected with the well of the astrophysical observatory at Potsdam. The depth of 25 meters was chosen for the pendulum room in order to avoid the diurnal effect of the sun's radiation and to secure a sand foundation for the pendulum pier. The sand foundation, being less affected by moisture conditions, was also a favorable factor in eliminating the causes producing the apparent deflections of the plumb-line.

It appears from the author's statement that the temperature of the pendulum room remained practically constant at 11.7° centigrade.

The pendulum used was a modified form of von Rebeur's pendulum, consisting of two small brass tubes joined at right angles to form a T, the top being the vertical axis. The upper bearing of the vertical axis was a spherical sapphire of about 2 millimeters radius. The lower bearing was a sapphire plane. These sapphire bearings rested against steel points on the pendulum supports. The horizontal bar of the pendulum carried a 40-gram weight near its outer end. Two such pendulums, at right angles to each other, were mounted in independent supports fastened to a heavy triangular iron bedplate provided with three foot-screws which sat in the footplates upon the pier. The two separate pendulum supports, carrying the two pendulums, rested upon small steel points, two of which were small steel balls fitting into conical holes in the bedplate. The line joining these two points was parallel to the horizontal axis of the pendulum, while the third, also a steel ball, was fastened to the end of a slow-motion screw which past up thru the bedplate. By means of this screw the position of the zero point of the horizontal axis of the pendulum could be adjusted. Adequate means were pro-

[1] Beobachtungen an Horizontal-pendeln über die Deformation des Erdkörpers unter dem Einfluss von Sonne und Mond—von O. Hecker—Veröffentlichung d. k. Preus. Geod. Inst., N. F. No. 32—Berlin, 1907.

[2] Brit. Association Report, York meeting, 1881, pp. 93–126.

[3] British Association Report, 1882, p. 95–119.

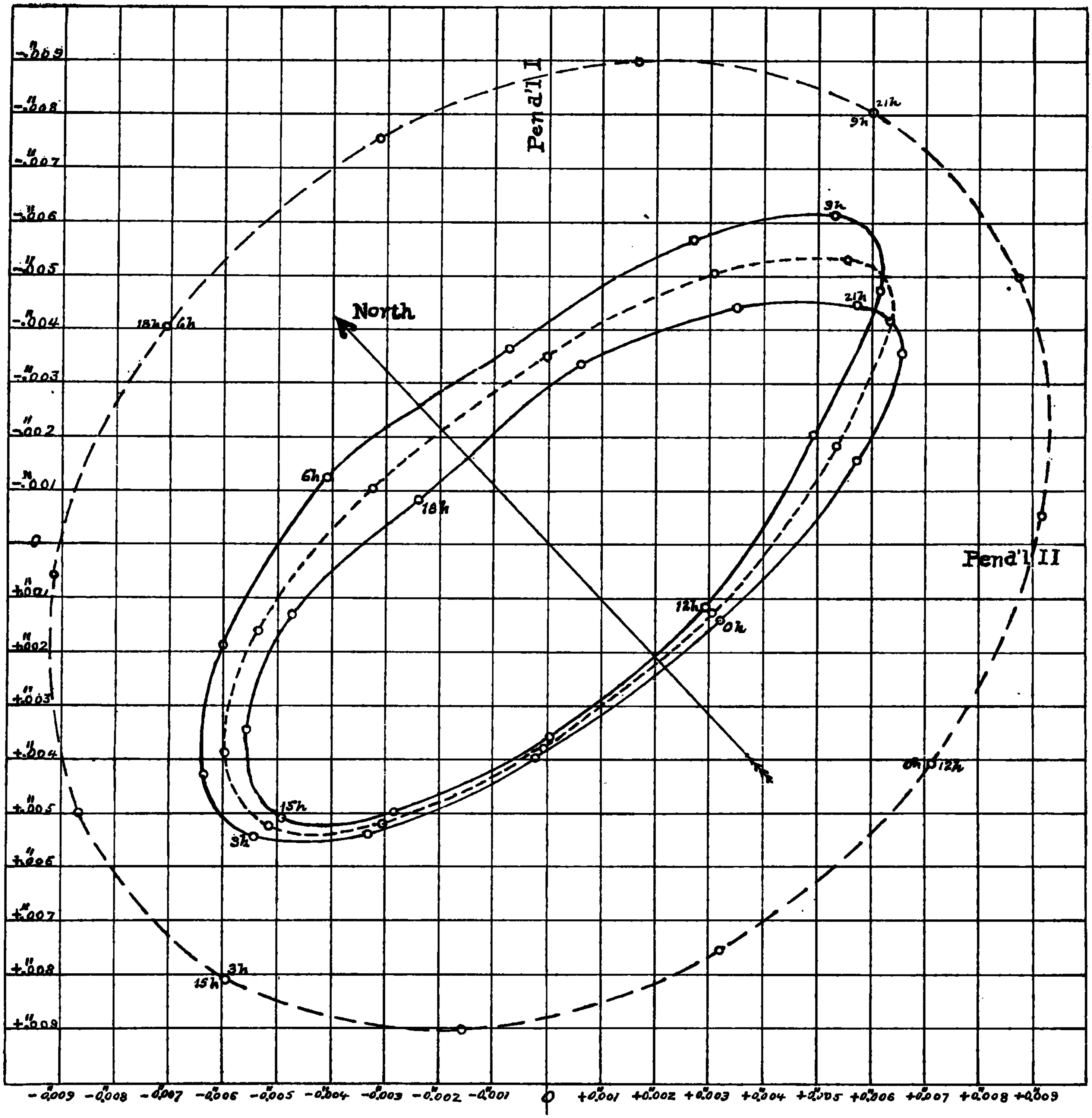

FIG. 1.—The motion of the plumb-line under the influence of the moon. Pendulum I pointed NE.; pendulum II pointed NW. (Reproduced from Veröff. d. k. preuss. Geod. Inst., Berlin ,1907, N. F., No. 32, Taf. VII.)
——— observed motion. - - - - - observed semidiurnal motion. — — — theoretical motion for absolutely rigid earth.

vided to protect the instrument from air currents and the steel suspension points of the pendulum from rusting. From the method of mounting the instrument, only one kind of metal being used, temperature fluctuations would not produce deflections of the pendulums. The pendulum designated as No. I (fig. 1), pointed approximately northeast or parallel to the long way of the room, while No. II was directed approximately northwest.

A continuous record of the position of the pendulum was obtained by the photographic process. The recording device was so arranged that two fixt lines were traced photographically upon the record sheet, one on each side of the pendulum record, so that the shrinkage of the record sheet could be more accurately eliminated. The time scale of the record was 12.5 millimeters per hour, which was amply sufficient for the purpose of the investigations. The recording apparatus was so arranged that a millimeter on the record sheet corresponded to a movement of the pendulum in the horizontal plane of about 28″. At the beginning of the series of observations, in the case of pendulum I, this movement corresponded to a deflection of the vertical of 0.0356″; at about the close of the series, twenty-six months later, it amounted to 0.0802″ per millimeter of ordinate. In the case of the pendulum II at right angles to pendulum I a corresponding change in the sensitiveness is noted, for which at the beginning of the series a millimeter of ordinate represented 0.0201″ deflection of the vertical, while near the close of the series it amounted to 0.0622″. It is thus seen that there was a very wide range in numerical value of the reduction factors, which for the whole period of the observations amounted to from two and one-half to three times their original value. While the author has not definitely ascertained the cause of this persistent decrease in the sensitiveness of the pendulums, yet he has stated his reasons for believing that it was not brought about by the wearing down of the steel suspension points, nor due to the inclination of the whole apparatus, but concludes that the cause must be inherent in the suspension of the pendulum upon points. He remarks in this connection that the decrease in the periods of the pendulum is unimportant, since the periods can be ascertained between the observed values with sufficient accuracy. However, it seems to me that the decrease in the periods of the pendulums as well as the shifting of the zero points is due to a gradual tilting of the pier to the northward. The effect of the shifting of the zero point was eliminated from the results by a method previously employed by von Rebeur,[4] in which it is assumed that the irregularity of the movement of the zero point is practically eliminated by dealing with the monthly means of each hour. From the monthly means of the hourly values correction coefficients were derived by which these mean values could be corrected for the gradual shifting of the zero point. Pendulum No. II, which was parallel to the shorter dimension of the room and directed toward the northwest, showed the greater irregularity in the motion of the zero point, and its total shift during the series of observations was about three times as much as for pendulum I, which was parallel to the longer side of the room. This change of the zero point of both pendulums appears to have arisen from the gradual sinking of the well, the masonry walls of which were in direct masonry contact with the pendulum room, thereby causing a tilting of the pendulum room and pier in a direction approximately toward the well.

In deriving the amplitude and phase of the periodic effect of the moon upon the pendulum the observations were divided into lunar months, thirty months being obtained from the whole series of observations. The monthly means for each hour were then combined into four groups, the first three groups each containing seven months and the fourth having nine months. A fifth group was also formed for the entire series of thirty lunar months. An expression is derived for each of the five groups in terms of a trigonometrical series and involving a daily, a half-daily, and a quarter-daily period.[5]

For the whole series of observations the following expression results for pendulum I, viz:

$$0.00057'' \cos(t-267.7^\circ)+0.00622'' \cos(2t-285.3^\circ)+0.00016'' \cos(4t-173.8^\circ).$$

Comparing the four similar expressions as derived from the four sections into which the series of observations was divided, it is seen that the coefficients of the daily and quarter-daily terms are quite small, and also that there is a wide range in the phase. Owing to the small magnitudes of the coefficients of these terms they can be considered negligible. But in the case of the half-daily term the coefficients and the phases show a good agreement; the resulting expression is, therefore, $0.00622'' \cos(2t-285.3^\circ)$, which clearly indicates the existence of the tide-generating force of the moon.

If we now compare the magnitude of this observed value with the computed value of the deflection of the vertical upon the assumption of an absolutely rigid earth, we should get definite indications of the earth's actual rigidity.

For computing the deflections of the vertical for an absolutely rigid earth the formula recently derived by Scheyder[6] was employed. By this formula the expression for the computed deflection is, for pendulum I, $0.00922'' \cos(2t-305.5^\circ)$. Comparing this expression with that derived from the pendulum observations it is seen that the observed deflection of the plumb-line, as caused by the moon's attraction, is about two-thirds of what it would be for an absolutely rigid earth; according to these observations the earth has about the same rigidity as a sphere of steel of like dimensions.

The observations are also discust with reference to the sun's effect in deflecting the vertical. The same methods were applied as in the case of the derivation of the moon's effect, except that the observations were grouped into calendar months. From the monthly means for each hour were derived the corresponding yearly means which were used in the trigonometric series to obtain the expression representing the observed effect due to the sun. The expression thus derived for pendulum I indicates that its motion under the sun's attraction consists of a daily oscillation upon which is superimposed a semidiurnal wave. The semidiurnal term is considered certainly to be due to the sun's attraction for the reason that there is a good accordance in this term as computed separately for each month, and its phase is about the same as that of the semidiurnal term derived for the moon. The observed semidiurnal term is $0.00244'' \cos(2t-277.5^\circ)$ for pendulum I.

For an absolutely rigid earth the computed sun's attraction is $0.00399'' \cos(2t-305.5^\circ)$ which is about in the same ratio to the observed value as was found in the case of the moon. In the case of pendulum II the coefficient of the observed semidiurnal term is too great, as it is in excess of that computed for an absolutely rigid earth. The observed and computed phase in that term are almost identical.

In the case of the measurement of the deflection of the plumb-line due to the sun's attraction two essentially greater difficulties are met with than in the case of the measurement of the moon's effect. First, the magnitude of the disturbance is only about half so great as for the moon, and the second and greater difficulty is due to the sun's radiation upon the surface of the ground, the effect of which is to cause a periodic fluctuation of the pendulum which may amount to many times the gravitational effect of the sun.

In the report of the British Association for the Advancement of Science for 1881 Prof. G. H. Darwin,[7] after reviewing his own experiments in the investigation of the lunar disturbance of gravity and the reports of others, states that "there can be little doubt that the surface of the earth is in incessant movement, with oscillations of periods extending from a fraction of a second to a year." By special experiments he also found the surface of the ground "to be in a state of continual vertitical oscillation."

Hecker's installation of pendulums at a depth of 25 meters below ground, and on a sand foundation, reduced the effect of the sun's radiation to about one-seventh of the surface disturbance, and practically secured a constant temperature.

[4] E. von Rebeur-Paschwitz, Horizontal-pendel Beobachtungen auf der K. Universitäts zu Strassburg. Beiträge zur Geophysik, Band II, Stuttgart, 1895, p. 245.

[5] Trigonometrical Series. "Die Ausgleichungsrechnung nach der Methode der Kleinsten Quadrate." F. R. Halmert, Leipsic, 1907, pp. 403, et seq.

[6] Beiträge zur Geophysik, Bd. IX, Heft I, pp. 41–77—"Ein Beitrag zur Bestimmung des Starrheitskoefficienten der Erde"—Wilhelm Scheyder.

[7] British Association Report, York meeting, 1881; p. 93-126.

As a final result the pendulum observations clearly show the tide-producing influence of the sun and moon upon the solid earth.

If we now compare the observed deflections with the values computed for an absolutely rigid earth, it is seen that the observed deflection due to the moon is about two-thirds of the amount for the rigid earth. If the earth were an absolutely nonrigid, homogeneous body, a change in the equipotential surface would result from the deformation of the surface shell produced by the sun's and moon's attraction, and consequently no movement of the pendulum would thereby be produced.

The effect upon the pendulum of the tides in the North Sea, the nearest body of water to Potsdam having appreciable tides, is computed to be 0.0006″ for a range of 1 meter in the sea level. As far as known, the nature of the North Sea tides is such as to decrease the above figure; their effect upon the pendulum may therefore be considered negligible. From all that is now known of the Atlantic Ocean tides, their effect upon the pendulum, as the author states, must be very small. The observations clearly yield evidence that, as the author states, "the solid earth does yield somewhat under the influence of the sun's and moon's attraction, yet offers great resistance to deformation."

The observations were analyzed with reference to the existence of a movement of the pendulum corresponding to the sidereal day; but no definite result was reached, except that, if such an effect exists, it must be very small, or, in other words, not measurable.

This series of observations has yielded evidence in good accord with that indicated from other directions, and when we consider the small magnitude of the measured quantities there is sufficient proof of the thoroness with which the observational work has been executed.

While it is not claimed that the results derived from this series of observations give an exact measure of the earth's actual rigidity, yet they do yield values based upon a direct measurement that must be considered a splendid approximation of the truth, and we are justified in believing that a great step forward has been made in thus definitely adding to our knowledge of an important physical fact.

SOME CLIMATIC INFLUENCES IN AMERICAN HISTORY.[1]

By WALTER N. LACY. Dated Cambridge, Mass., June 26, 1908.

"Of all natural forces influencing the life of a nation," says Prof. Edward Channing (**2**, p. 2), "the climate and rainfall are the most important, because an excess of cold or an absence of rain forbids the development of human activity." In connection with recent studies, the writer has had occasion to note some of these climatic influences in the history of the United States and this paper is an attempt to present some of these influences without chronologically considering the possible climatic controls in every chapter of American history.

Climate is complex and controlled by many factors. Hence, the fact must be borne in mind that whatever influence it has had upon the life of a people, it has not acted independently. Geographic and other factors enter into the controls of history to such an extent that even where any one of them has had an important influence, to it can rarely be attributed the whole cause of the events which have been so vitally affected thereby. The influence of those climatic controls on the history of a nation is, perhaps, too seldom considered, important tho these controls are. It is, therefore, the hope of the writer that this paper may lead to a wider appreciation of climatic influence on history.

DISCOVERY.

Why not earlier.—Whether the American Indian came originally from China or Japan is a question which the historian still leaves to the archeologist. It seems certain, however, that if he did come from Asia, all communication between the American and his Asiatic brother was subsequently terminated. When Columbus first saw the New World in 1492, it was an unknown world—neither Europeans nor Asiatics knew of its existence. Why, it is then natural to ask, had the American Continent not been discovered and made known before? This question seems especially pertinent in view of the close mutual approach of these continental masses at the north. The answer lies, doubtless, in the fact that this proximity was found only at these high latitudes. Had it not been for the rigorous climate which exists along the northeastern coasts of Asia and North America, it seems probable, if not certain, that America would have been known to the rest of the world some centuries prior to the fifteenth. Those were the days when ignorance and superstition, coupled with unseaworthy ships, prevented the mariner from venturing far from the shore; hence, to discover America from either Europe or Asia was possible only by cruising along the coasts, and crossing from one continent to the other where the two most closely approach each other. This was prevented by the hostile climate which had to be encountered, for food supplies could not be secured on these inhospitable coasts. As Professor Shaler has pointed out (**13**, p. 6), "the scanty food-carrying power of the ancient ships, whether of Europe or Asia, made it almost impossible for an expedition to pass from the Old World to the New World by coasting along the arctic shores, and thus to attain the fertile lands of America in a condition to meet the dangers which newcomers have to face in an unknown land." Under these conditions, had the continent been discovered by Europeans or Asiatics, the discovery could not have been followed by settlement, and the fact of the discovery would probably have been forgotten.

The Northmen.—While it is doubtless true that America was an unknown continent in the fifteenth century, nevertheless, Columbus can not lay claim to the honor of being the first white man to see its shores. Here, again, climatic influences have played an important part. Climatic and other geographic conditions had made the people of Scandinavia a sea-faring people. A thousand years ago Iceland was a European colony, and a settlement had been planted near the southern end of Greenland. Ivar Bardsen, steward of the Garder Bishopric in the latter half of the fourteenth century, recorded that there had been a gradual southward extension of drifting ice and of the Greenland ice-cap, and the fact that "herds of cattle were kept which even yielded produce for exportation to Europe," (quoted in **6**), has further led to the conclusion that Cape Farewell had a slightly milder climate a thousand years ago than it has to-day. But whether or not this was the case, it seems certain that a colony of Northmen flourished for a time near this place.

"With the Northmen once in Greenland, the discovery of the American Continent was almost inevitable" (**6**, p. 178). However mild the climate of Greenland may have been, the land does not seem to have been well-wooded, and Laing has pointed out how natural it was that the colonists there should seek the abundant and cheap fuel supply which the driftwood, floating from the southwest, indicated was to be found in that direction. With the prevailing westerly winds and the Gulf Stream, it is highly probable that driftwood from the American forests was floated across the sailing route between Greenland, Iceland, and Scandinavia, and in quest of this lumber the Northmen may have ventured. Or a storm, setting in fiercely from the northeast, would easily have driven these bold sailors from their courses, and landed them on the western coast of the Atlantic.

[1] A thesis prepared in 1908, under direction of Prof. R. De C. Ward, for an advanced course in climatology at Harvard University.
References to the numbered bibliography are given in the parentheses by heavy-faced numbers.